24GHz Working Breakfast – Questions and Answers from the experts

Michael Fletcher...

1) Please describe in detail the antenna and equipment that you used in receiving the 24GHz TX from AO-40? (I have a block diagram of you equipment from your website)

I started off with using my regular troposcatter rig and dish system. The dish is a modified commercial 22/23 GHz microwave radio dish. The main modification is adding three screws at lambda/8 spacing for fine tuning the matching. The feed has not been modified in any way. Adequate operation can be verified by making sky/ground and sun/sky noise comparison measurements.

The receiver in this rig (I have two, the other one used homemade amplifiers and mixers) is based on DB6NT modules. The LO and mixer I built myself, but the LNA (and SSPA) came ready assembled and tested. Building your own LNA will require experience and also test equipment to verify that there are no oscillations etc.

In this setup, you must realize that 1 - 2 dB loss is added to the receiver LNA noise figure from the microwave relay and waveguide structures that would not be required in a pure AO-40 receiver. Achieving a noise figure of less than 2 dB is possible with current day devices on PTFE substrate.

This first experiment with the 60 cm dish was to initially verify correct operation of the K band TX.

2) How difficult is the dish positioning required to track a signal? What type of dish mount do you use?

For the 60 cm (tropo) rig I used my regular setup: a solid tripod with azimuth/elevation scales with 1 and 2 degree resolution respectively. 1 degree pointing accuracy (not just resolution, but also ACCURACY) is pretty much necessary to easily find the bird. Also upto date Keplers are required, though these degrade pretty slowly. I have found that at least TrakSat and FodTrack both give pretty consistent and reliable pointing data. FodTrack is my favourite for Doppler calculation, simply because it works and is accurate. No Windows either ;-)

3) What is the beamwidth of your antenna? gain, etc.

You can approximate the beamwidth (-3 dB, E-field) from:
Beamwidth = 73 * wavelength (cm)/dish diameter (cm)

For 24048 MHz this will give (wavelength ~1.25 cm):

60 cm dish -> 1.5 degrees

120 cm dish -> 0.8 degrees

3 m dish -> 0.3 degrees

The gain can be calculated from:

G = 4 * pi * A(eff) / (lamda squared)

A(eff) is the effective aperture. The actual aperture, A, is the collecting surface area of the dish, so it is simply:

A = pi * R * R R being the dish radius, i.e. half the diameter

A(eff) is pretty much less than this due to illumination deficiencies, surface accuracy, reflections from structures etc. A reasonable effiency is in the range of 55 - 65 %. Take 55 % to be on the "safe" side of things, i.e. multiply A by 0.55 to get A(eff) to plug into the equation above for gain.

G(dB) if of course 10 * log (G)

for the dishes above:

60 cm -> G = 22739 multiplied by 0.55 gives 12506, or 41 dBi

90 cm -> G = 51164, multiplied by 0.55 gives 28140, or 44.5 dBi (haven't tested my 90 cm dish on AO-40 yet...)

120 cm -> gives 47 dBi (6 dB more than the 60 cm dish or course...)

300 cm -> gives 55 dBi

4) I see that several different size dish antennas were used - why is this? What are the benefits/negatives of a small dish? a larger dish?

Of course the smaller dish is MUCH easier to point. A 60 cm dish may just barely be controllable with a good rotator with a good electronic speed control. The typical backlash is considerable compared to the beamwidth. When the bird is near apogee, the pointing of the 60 cm dish needs to be readjusted every 5 - 10 minutes to keep hearing the thing properly...

A large dish will give you better C/N ratios of course, but you will also find that the pointing is critical to say the least.
You would need a good LNA on a 60 cm dish to copy the TX reasonably, but a 90 cm dish might be the ideal, as you will loose 3 dB by going circular polarised (necessary to avoid spin modulation).
If Karl Meinzer's software for driving the momentum wheels is a success, and I personally believe it will be, then the rotation of the spacecraft will be really slow. If you build your dish so that the linear polarisation is rotatable (by rotatind the feed to find max. signal strength), then the signals will stay excellent for the rest of the apogee path (many hours). I have constructed circular polarisation feeds for many bands and started experimenting with K band too, but I have nothing documented yet. With circular pol. it is of course possible to decode the telemetry 100 %.
G3WDG has been doing this on the last couple of passes.

I used the 1.2 m dish and will be using the 3 m dish for reasons of making some passband measurements to compliment my P3D/AO-40 test documentation for later reference (I have fully documented all RF/Microwave tests during Thermal Vacuum, Crosstalk/IMD testing, post-vibration testing and also during the launch

campaign in Kourou; documenting the operation of equipment on board AO-40 - In Orbit Testing if you will - is for finalizing this important work. There is absolutely no reason for any ham to use anything bigger than around 1 m or so for receiving K band. With a good LNA and low loss feed system, you should be able to copy the TX passband noise with low squint.

5) Is circular polarization possible at 24GHz? Will a linear feed be sufficient?

Linear pol. will be OK if the s/c is eventually 3-axis stabilised. Using circular pol. will get rid of the spin modulation at the cost of loosing 3 dB in signal strength.

6) Was the fade severe due to satellite spin?

Yup.

7) Do you have any equipment you are working on to improve your reception?

Not as such. I have planned on building a dedicated 24048 receiver for AO-40, but I have some other commitments first, presentations and such to prepare, along with live demos for the OH folks.

8) Have you been able to receive any good blocks from the 24GHz receiver using AO40RCV?

Not personally, but I am 100 % confident that this can be done by using circular polarisation. But maybe Karl can get the 3-axis stabilisation running soon. Of course there is still a lot of work to be done before the decision to go 3-axis stabilised can be taken; contingency plans, risk analysis etc.

9) Have you seen the DB6NT 24GHz amateur equipment? What do you think of it?

Yes, seen and used. The work is excellent and highly recommendable if you can afford it. I have no affiliation with Michael whatsoever, I just feel proud that a fellow ham is producing professional grade devices for the ham community...

The DB6NT concept used a starved LO subharmonic mixer, where the LO is half the required, i.e. about 12 GHz.

10) Is there any commercial equipment that can be converted to work for receiving 24GHz?

Yes, but this is hard to come by (at least in Finland). Most recent (surplus) radios are frequency synthesized - a must for even considering use for AO-40. The ones I have seen have LNA's, SSPA's, waveguide filters, MMIC amplifiers, balance diode mixers etc. The older 23 GHz band radios use Gunn oscillators and waveguide mixers. These are not suitable for AO-40, except for the filters, mixers, circulators, isolators, waveguide and the antennas. The LO MUST be xtal controlled and in most cases the PLL synthesizers are good enough for CW/SSB.

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The Gunn oscillator based radios make excellent test equipment:
the Gunn oscillators are in general tunable to our band and also
often feature varactor modulation for FM. The varactor enable
using the Gunn osc. as a sweep oscillator. The Gunn diode itself
can be 100 % AM modulated at 1 kHz via the power supply, so you
can use the surplus SWR meters available on the market for
very wide dynamic range testing, antenna radiation patterns,
filter tuning etc.

In short: you will need to either buy or purchase a ready made
LNA for 24 GHz. Also the LO may need to be purchase or constructed
or at least the possible synthesizer may need a new crystal, but
all the other 23 GHz band radio stuff is very useful indeed.

Especially the antennas...

Regards,
Michael, OH2AUE

24GHz Working Breakfast – Questions and Answers from the experts

Charlie Suckling...

1) Please describe in detail the antenna and equipment that you used in receiving the 24GHz TX from AO-40? (I have a block diagram of Michael's equipment from his website)

Basic receiver the same for the two systems tried so far. Consists of DB6NT ready-made 30dB gain preamp (DB6NT claimed NF=1.55 dB), length of flexiguide (sonce replaced with 1db loss coax) into main RX. Main RX consists DDK004 2.4GHz LO, WDG009 2.4-12GHz multiplier/PA, DB6NT Mk 2 antiparallel diode mixer (homebuilt), WDG design waveguide cavity image rejection filter, and a a couple of FET gain stages. Overall NF of main box approx 4-5dB.

2) How difficult is the dish positioning required to track a signal? What type of dish mount do you use?

Present system has the 24GHz dish attached via a boom to the (10ft) S-Band dish mount. This uses sat tv type linear actuators to move dish in el/az, at approx 0.25 deg/sec slew rate. No computer control, just l, r, up, down buttons. With present 60cm dish size, tracking is no problem, but narrower beamwidth than 10ft on S-Band.

3. What type antenna? gain, etc.

Two antennas so far: 18 x 22cm offset dish and 60cm offset dish. Smaller antenna used to make finding signal easier with no proper mount available initially (system on top of a workmate) as we had less than 12hr notice of the first K-Band test. Moved to larger dish as signal levels were marginal with smaller one and no chance of good telemetry. No gain figures measured - you can calculate approx from apertures if needed.

4) I see that several different size dish antennas were used - why is this? What are the benefits/negatives of a small dish? a larger dish?

See above. I would use as large ant as possible consistent with being able to point it!

5) Is circular polarization possible at 24GHz? Will a linear feed be sufficient?

I am using circular polarisation now using a dielectric polariser (see photos). Linear feed OK to get started to hear signals, but as long as sat is spinning as at present, there will always be severe QSB. QSB absolutely ruins tlm collection and makes signals more difficulty to copy.

6) Was the fade severe due to satellite spin?

Yes, you get two nulls per rev of sat spin as polarisation goes thru 90 deg and 270 deg.

7) Do you have any equipment you are working on to improve your reception?

This week, hope to commission the 10ft dish for 24Ghz reception. Will start by grossly under-illuminating it with a high gain feed (mounted

inside an S-Band helix) to make the dish look like a 5-6ft dish. Hoping that careful peak-up on S-Band will get K-Band close enough to find the signals (we'll see!).

8) Have you been able to receive any good blocks from the 24GHz receiver using AO40RCV?

Yes, occasionally. Main problem is the level of the beacon drops below threshold when passband contains strong signals. K-Band differs from S-Band in that beacon level is affected by level of what is going on in the passband (.wav files of this attached). Blocks are CRC OK with beacon at its max level. A040rcv also tracks the Doppler shift well (I use the rig tune feature and it locks very well). Attached tlm file of 3 good blocks from about a week ago.

9) Have you seen the DB6NT 24GHz amateur equipment? What do you think of it?

Technically very good.

10) Is there any commercial equipment that can be converted to work for receiving 24GHz?

Not that I have seen, but I'm not interested in converting surplus so am probably the wrong person to ask. Wideband Gunn stuff certainly of no use at all.